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SELECTION OF MINIMUM DAY/NIGHT
LEVELS FOR NOISEMAP CONTOUR
CALCULATIONS

Dwight E. Bishop

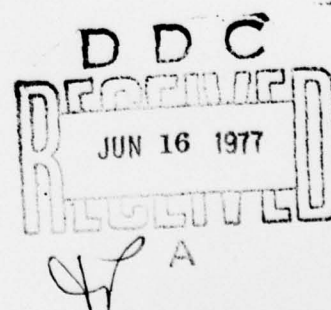Bolt Beranek and Newman Inc.
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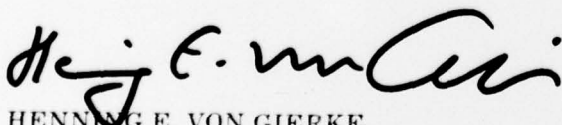> Cameron Station
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AMRL-TR-76-124

This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

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FOR THE COMMANDER

HENNING E. VON GIERKE
Director
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This report discusses guidelines for the minimum Day/Night Level (DNL) values that should be used with NOISEMAP type computations to: (1) insure adequate accuracy of the lowest contour level for a given set of aircraft operations; and (2) minimize the number of machine computations and thereby reduce operating costs. An analysis is made of the errors introduced in the DNL contour values due to truncation of the "partial" DNL cutoff determined

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by the single event noise level or the number of aircraft operations for a particular flight path. For a given airbase and fixed volume of aircraft operations, the cutoff occurs at higher single event noise levels as the number of aircraft flight paths or aircraft classes are increased. Finer detail in describing the aircraft operations results in the cutoff noise levels being raised with an increased error at the edges of the DNL grid computations, but with a corresponding decrease in the machine running time. These DNL cutoff guidelines have been incorporated into version 3.4 of NOISEMAP.

PREFACE

This report is one of a series describing the contractual and in-house research program undertaken by the Aerospace Medical Research Laboratory under Project/Task 723104, Measurement of Prediction of Noise Environments of Air Force Operations, and develop a procedure for predicting the community noise exposure resulting from aircraft operations. Other reports previously published under this research program include: AMRL-TR-73-105, "Community Noise Exposure Resulting From Aircraft Operations: Application Guide for Predictive Procedure"; AMRL-TR-73-106, "Community Noise Exposure Resulting From Aircraft Operations: Technical Review"; AMRL-TR-73-107, "Community Noise Exposure Resulting From Aircraft Operations: Acquisition and Analysis of Aircraft Noise and Performance Data"; AMRL-TR-73-108, "Community Noise Exposure Resulting From Aircraft Operations: Computer Program Operator's Manual"; AMRL-TR-73-109, "Community Noise Exposure Resulting From Aircraft Operations: Computer Program Description"; AMRL-TR-73-108, Appendix "Community Noise Exposure Resulting From Aircraft Operations: NOISEMAP Program Operator's Manual"; AMRL-TR-73-108, "Addendum For Version 3.3 of NOISEMAP". Technical monitor for this effort was Mr. Jerry Speakman of the Biodynamic Environment Branch. Partial funding for this effort was provided by the Air Force Civil Engineering Center, Tyndall AFB, Florida.

SELECTION OF MINIMUM DAY/NIGHT LEVELS
FOR NOISEMAP CONTOUR CALCULATIONS

I.   INTRODUCTION

This technical memo provides recommendations for selecting minimum
day/night level (DNL) values in NOISEMAP computations. The
recommendations are based upon interpretation and analysis of a
simple calculation model which is described in detail in the
Appendix.

II.   TECHNICAL DISCUSSION

In NOISEMAP computations, two limits for DNL computations can be
specified:

(a)   Noise contributions from aircraft flight paths may be
       dropped when the sound exposure level (SEL) for that
       aircraft drops below a given value. Alternatively,
       noise level contributions from an aircraft may be
       dropped when the distance from the aircraft exceeds a
       maximum value.

(b)   Contribution from an aircraft flight path may be dropped
       when the "partial" DNL value for that particular flight
       path falls below a minimum value. This cutoff is
       determined by both the noise level *and* the number of
       operations on the flight path.   Thus, for a given
       airport and fixed volume of aircraft operations, the
       cutoff occurs at higher SEL values as the numbers of
       aircraft flight paths and aircraft classes are increased.
       Hence, as one gets more sophisticated by providing finer
       detail in describing aircraft operations, with an
       attendant increase in aircraft classes and tracks, the
       cutoff noise levels are raised with increased
       error at the edges of the grid computations.

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Figure 1 (from Reference 1) provides an estimate of the noise
level cutoff as a function of the effective number of operations,
for a cutoff value of DNL 42 (or NEF 7). Note that the cutoff
result in a truncation of noise levels near the edges of the
grid path roughly shown below.
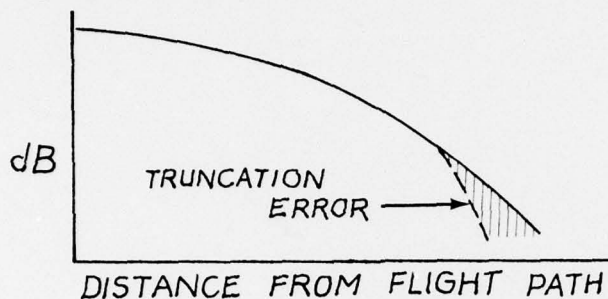
Generally, the errors introduced by truncation will be largest
when there are near equal contributions from many flight paths
and aircraft. For a given error in grid computations, the
resulting contour error will generally be greatest when the noise
exposure gradient is small; the contour error will be least when
the gradient is large.

One needs to specify a cutoff value in order to limit the number
of computations. However, the limit should be set to hold
possible truncation errors to a small finite quantity. In
practice, one cannot easily determine the number of "partial"
DNL values that contribute to the total DNL at each grid point;
this number will vary widely with the grid point location.
Faced with this situation, one approach is to estimate the likely
worst case situation for a given airport, and select a cutoff
that would limit the errors of this worst case situation.

To provide some insight into potential DNL calculation errors,
a simplified situation is assumed, where a number N of partial DNL
values, L_i, contribute to a total DNL value, $\overline{L}_N$. These partial

values are assumed to be uniformally distributed over a total DNL range, ΔL, with a constant difference in level, K, between any two partial values. This situation is sketched in Figure 2.

The partial values can be summed to obtain the total DNL value $\overline{L}_N$. When a DNL cutoff, L_c, is introduced that exceeds the lowest partial DNL value, one or more DNL values are dropped in calculating the total DNL. Thus, there will be a difference (or error) between the computed DNL value $\overline{L}_x$ and the true total DNL value.

Using the equations given in the Appendix several series of calculations were made to determine the difference between the total DNL value and the cutoff value (approximately represented by the quantity y in Figure 2) for specified errors in calculation of 0.5 and 1.0 dB. The results of these calculations are shown in Figure 3 and 4. Figure 3 shows that for a given range of partial DNL values (in this example, 20 dB), the value y increases almost linearly with the logarithm of the number of partial DNL values.

In Figure 4, the number of partial DNL values is held constant at 21, while the range of the partial DNL values is varied from 5 to 40 dB. In this situation, the value of y shows a small decrease as the range of partial DNL value is increased beyond about 10 dB.

From inspection of these two figures, the dominating influence on y is the total number of partial DNL values as indicated in Figure 3. A straight line fitted to the 0.5 dB error curve in Figure 3 over the range from 10 to 100 partial DNL values gives the following:

$$y = 0.6 + 11.7 \log N \tag{1}$$

Note that the slope (11.7) is slightly greater than the slope
of 10 that would result when the range y goes to zero.

Now in actual computations, it is obvious that not all flight
segments will provide significant contributions to the noise at
any given spot. For a worst case situation, the number of potential
flight segments is proportional to the total number of flight
cards reduced by a factor related to the number of active airport
runways and gross number of flight tracks. Thus, this consideration,
together with Equation (1) leads to the following expression for
setting the cutoff limit for individual flight track DNL calculations:

$$L_c = L_o - 11.7 \log \frac{N}{R+1} \qquad (2)$$

where L_o = value of the minimum DNL contours of interest

L_c = cutoff DNL value

N = total number of flight track cards

R = number of active physical runways

The above should result in calculation errors that do not exceed
0.5 dB, and, in most situations, should result in errors of
appreciably less than 0.5 dB.

REFERENCES

1. D. E. Bishop, "Review of NOISEMAP Contour Calculation Program
    Parameters That Influence Noise Contour Accuracy", BBN
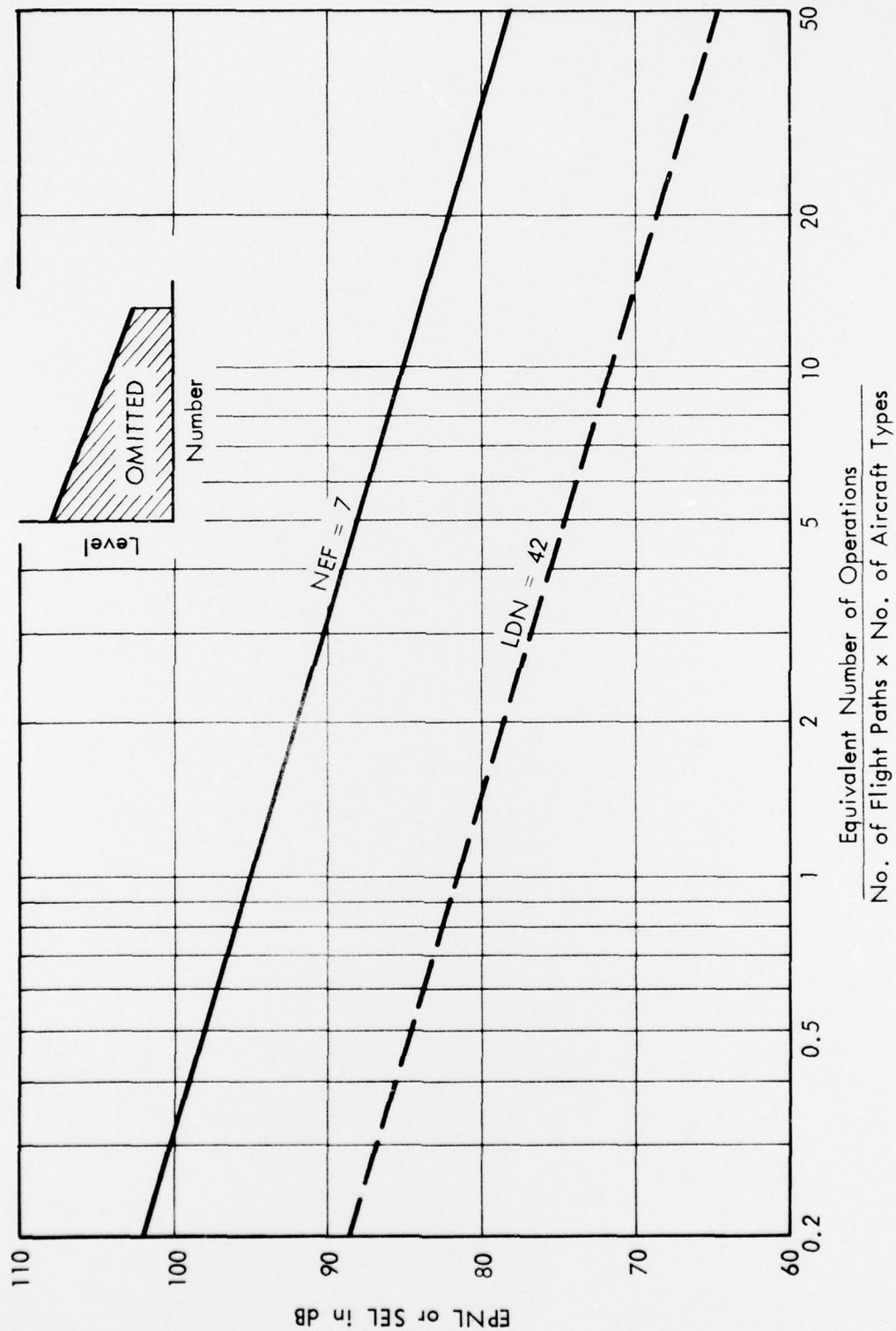   Technical Memorandum, September 1975.

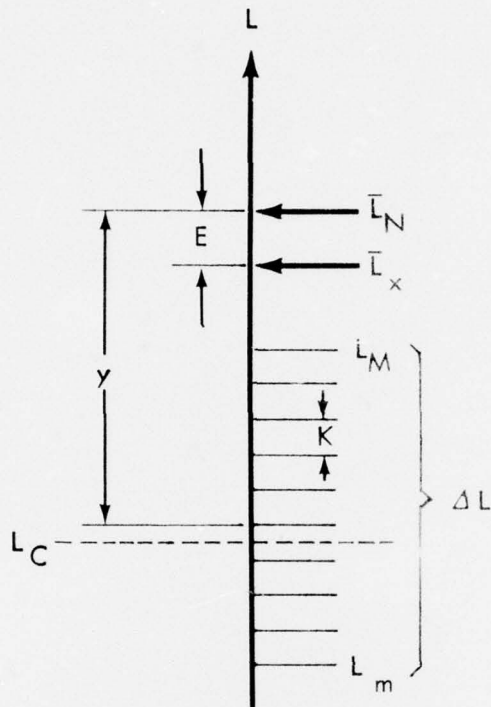FIGURE 1.   APPROXIMATE NOISE LEVEL CUTOFF DUE TO "PARTIAL" NEF OR LDN CUTOFF IN COMPUTATIONS

FIGURE 2.   RELATIONSHIP OF LEVELS FOR DAY-NIGHT
LEVEL CUTOFF ERROR ANALYSIS

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APPENDIX

CUTOFF ERROR ANALYSIS

Assume N "partial" DNL values, L_i, at a given ground position, contributed by individual aircraft flight segments. Assume the L_i values are uniformly distributed over a total DNL range, ΔL, with a constant difference in level, K, between any two partial values. Thus, the L_i values are evenly spaced between a maximum value, L_M and a minimum value, L_m where:

$$L_m = L_M - (N-1)K \tag{1}$$

The "total", or combined DNL value $\overline{L}_N$ is:

$$\overline{L}_N = 10 \log \sum_i 10^{\frac{L_i}{10}} = 10 \log \sum 10^{\frac{L_M}{10}} + 10^{\frac{L_M - K}{10}} + .. + 10^{\frac{L_M - (N-1)K}{10}}$$

or

$$\overline{L}_N = \left(L_M - (N-1)K \right) + 10 \log \frac{k^N - 1}{k-1} \tag{2}$$

where $k = 10^{\frac{K}{10}}$

When the DNL cutoff (L_c) exceeds the minimum DNL value, one or more DNL values are dropped in the summation, $\overline{L}_x$. Hence, there is a difference (or error, E) between the computed $\overline{L}_x$ and the "true" $\overline{L}_N$, where

$$E = \overline{L}_N - \overline{L}_x \qquad\qquad \text{(dB)}$$

In selecting DNL cutoff values appropriate to the desired noise contour situation, the question arises as to what is the maximum cutoff value for a specified error, E. Or, alternatively stated, for an error equal or less than a specified value of E, what is the value of y where:

$$y = \overline{L}_N - (L_M - xK)$$

The calculation situation is sketched in Figure 2.

The computed DNL value, $\overline{L}_x$ is given by:

$$\overline{L}_x = (L_M - xK) + 10 \log \frac{k^{x+1} - 1}{k-1} \qquad (3)$$

For a specified value of E, the values of x and y can be determined from trial and error solution of the following:

$$10^{\frac{L_M \cdot xK}{10}} (k^{x+1} - 1) = \frac{10^{\frac{L_M - (N+1)K}{10}} (k^N - 1)}{\xi} \qquad (4)$$

where $\xi = 10^{\frac{E}{10}}$

Equation (4) was used to calculate the curves of Figure 3 and 4.
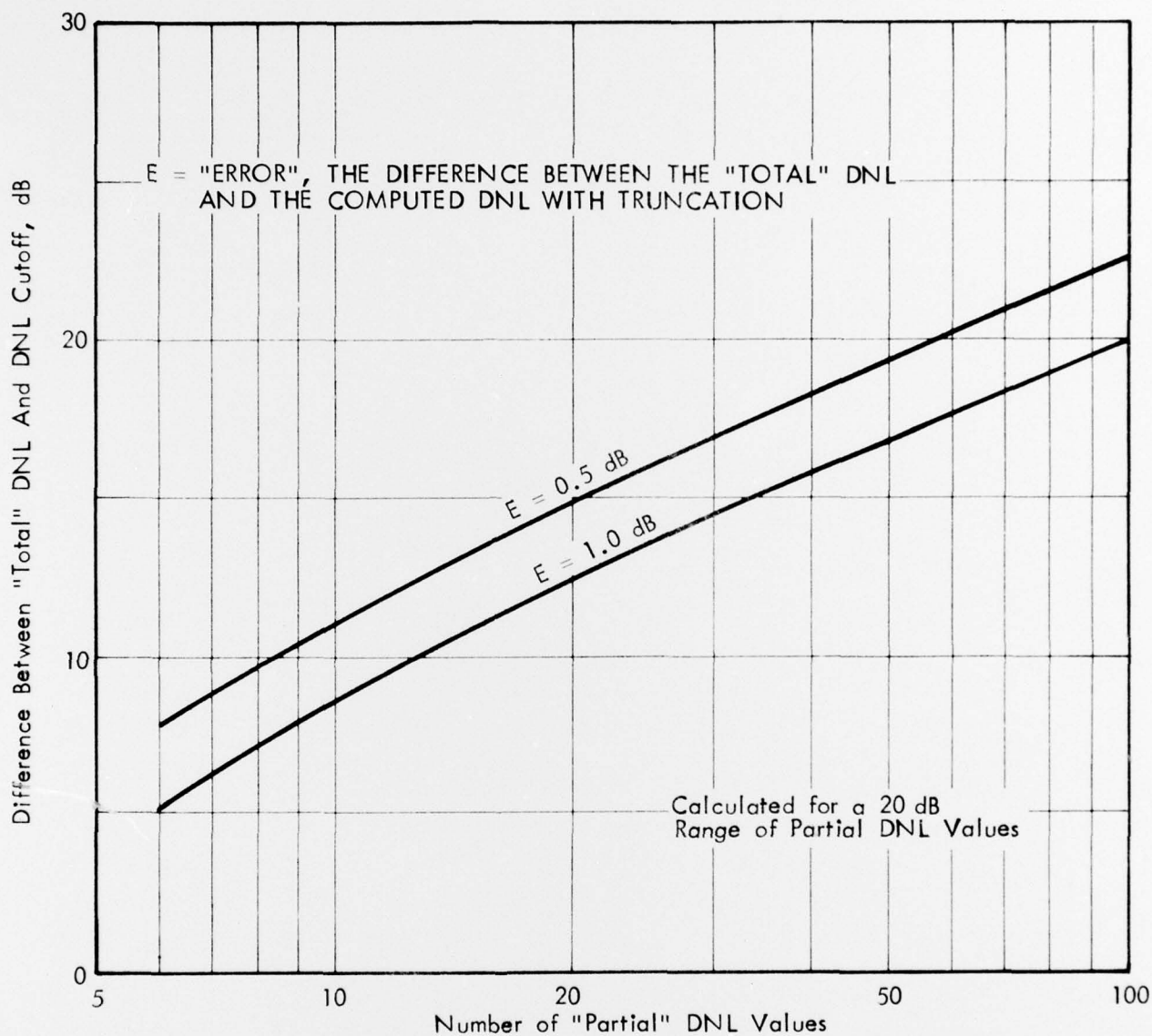
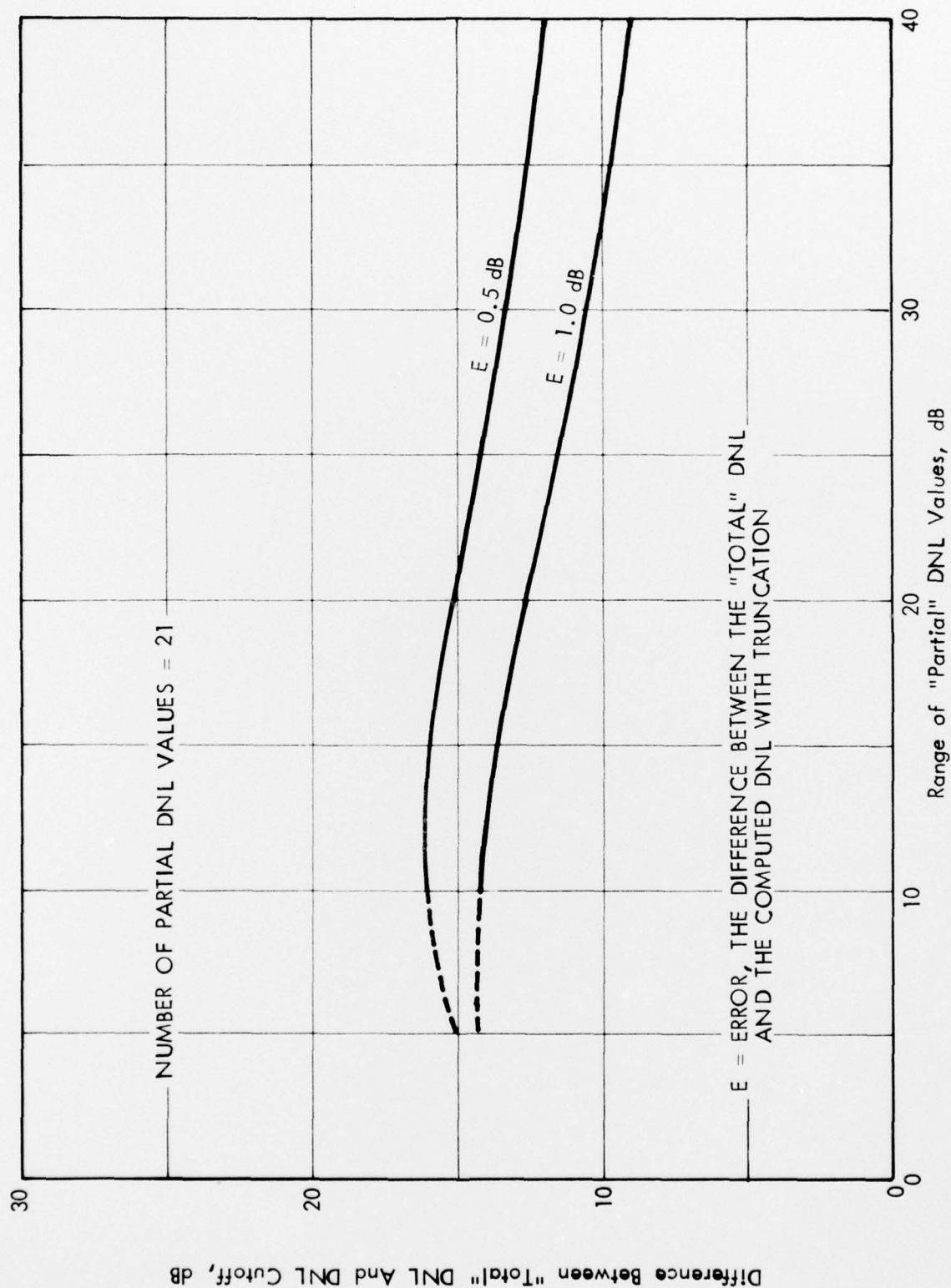FIGURE 3.   CUTOFF ERROR VARIATION WITH NUMBER OF PARTIAL DNL VALUES

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FIGURE 4. CUTOFF ERROR VARIATION WITH THE RANGE OF PARTIAL DNL VALUES